Engineering Structures 33 (2011) 90–98

Contents lists available at ScienceDirect

Engineering Structures

journal homepage: www.elsevier.com/locate/engstruct

A method to assess peak storm wind speeds using detailed damage surveys

Gregory A. Kopp*, Murray J. Morrison, Bahareh Kordi, Craig Miller

Boundary Layer Wind Tunnel Laboratory, Faculty of Engineering, University of Western Ontario, London, ON, N6A 5B9, Canada

ARTICLE INFO

Article history:
Received 13 April 2010
Received in revised form
3 June 2010
Accepted 16 September 2010
Available online 29 October 2010

Keywords:
Wind loads
Damage surveys
Downbursts
Wind-borne debris
Low-rise buildings

ABSTRACT

A detailed damage survey of a single, wood-framed, structure, which had a complete roof failure during the passage of a gust front in southern Ontario, was performed. Radar data was used to estimate upper level wind speeds associated with the gust front. Details pertaining to the structural failure, including the debris field, were obtained. Wind tunnel pressure time histories, in a simulated atmospheric boundary layer, were used to establish the roof height, gust wind speed at failure. This speed was smaller than the upper level speed found from the analysis of the radar. The flight of the roof was also examined, and confirmed the wind speeds obtained from the structural analysis of the failure. The study illustrates that detailed damage surveys, which incorporate the use of wind tunnel test data and debris flight in the analysis, can shed considerable light on the details of the wind speeds at failure, reducing the uncertainty caused by the many assumptions in such analyses.

1. Introduction

It is now common to conduct damage surveys following large storms (such as hurricanes and large tornadic events) to capture overall damage and repetitive patterns of failure. The results of such studies are important to solving problems caused by severe wind storms. It is also important to have knowledge of the wind speeds which caused the damage in order to assess design practice, construction methods and building codes. These speeds are rarely available at the surface in thunderstorm winds, where the structures are and where the damage occurs, although they are now more routinely measured in hurricanes (e.g., [1]). The current study is focussed around the question of determining wind speed from damage, and takes the approach of finding detailed case studies which can illuminate the issues around this, such as, for example, the bounds of the peak gust speeds and the duration of such peaks. In particular, the current study focuses on using both (structural) failure observations and subsequent debris flight to infer both the upper and lower bounds on the wind speeds, rather than just the lower bounds associated with the failure observation. In order to accomplish this, other tools are required, and in the current study, both scale model wind tunnel experiments and numerical analysis of debris flight are utilized.

One issue, where there is currently little information, is the role of unsteadiness and gust duration during downbursts, microbursts and gust fronts. Wind-induced pressures in boundary layer (or hurricane) winds typically have short duration peaks, but little is known about these for thunderstorm (downburst) winds. For boundary layers, peak pressures are of shorter duration for higher wind speeds and are typically less than a few seconds (and often less than a second) for damaging winds in hurricanes. However, downbursts appear to have steadily increasing speeds over a longer time frame, on the order of tens of seconds to minutes, so it is not clear whether different aerodynamic phenomena and gust structures are involved with the peak pressures and failures.

One method to infer wind speed from damage has been to use pressure coefficients in the wind provisions of building codes such as the ASCE 7-05 [2]. To do this is a significant assumption, particularly if the damage is to smaller wood-frame structures such as houses. The reason for this is that the MWFRS coefficients were developed to envelope wind tunnel data and were obtained for buildings generally of much larger size than typical houses, for example. Surrounding structures also alter the loads in less than straightforward ways. To address this, we have analyzed detailed wind tunnel pressure data for the failed building, considering local terrain and surrounding details. Obviously, this cannot be done for each structure in a large storm, but for particular case studies, we believe it is beneficial. One of the objectives of the current work is to describe such a methodology. In conjunction with detailed aerodynamic data, the structural response is also crucial. It is well known that the fluctuating pressures on a structure have substantial gradients over the building surfaces and this has a profound effect on the performance of the structure and the failure mode, particularly for massively statically-indeterminant structures like wood-frame houses with relatively small spacings between trusses (compared to the metal frame buildings used in the development of the wind load provisions, such as in ASCE 7-05 [2]). Recent, laboratory-based, full-scale tests to failure at

* Corresponding author. Tel.: +1 519 661 3338; fax: +1 519 661 3339.
E-mail addresses: gakopp@uwo.ca, gak@blwtl.uwo.ca (G.A. Kopp).

0141-0296/$ – see front matter © 2010 Elsevier Ltd. All rights reserved.
doi:10.1016/j.engstruct.2010.09.021